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THE THREE R'S PLUS OR A NEW APPROACH TO EDUCATION'S PROBLEMS.

BY- OXHANDLER, EUGENE K. TAYLOR, ELEANOR C.
SYRACUSE UNIV., N.Y.

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CONCERN OVER THE FOLLOWING QUESTIONS LED TO A CONFERENCE HELD APRIL 2-4, 1964 AT SYRACUSE UNIVERSITY--(1) WHAT POTENTIAL DO NEW TECHNOLOGIES HAVE FOR SOLVING SOME OF THE URGENT PROBLEMS IN THE FIELD OF EDUCATION AND (2) HOW CAN AN AUTOMATED SYSTEMS APPROACH, SPECIFICALLY OPERATIONS RESEARCH, BE APPLIED TO DEVELOP NEW DIMENSIONS FOR RESEARCH THAT WILL RESULT IN IMPROVED INSTRUCTION IN SCHOOLS. THIS MONOGRAPHY WAS BASED ON MATERIAL PRESENTED DURING THE CONFERENCE WHICH WAS ATTENDED BY 40 LEADING EDUCATORS AND SCIENTISTS. HIGHLIGHTS OF DISCUSSIONS ON CONTRIBUTIONS, RESULTS, AND DIFFICULTIES OF OPERATIONS RESEARCH APPLICATION IN EDUCATION WERE DISCUSSED. PRIMARY AUTHORS WHOSE PAPERS WERE INCLUDED IN THE APPENDIX OF THE MONOGRAPH WERE (1) DR. RUSSELL L. ACKOFF, WHARTON SCHOOL OF FINANCE, (2) DR. CARL A. BENNETT, GENERAL ELECTRIC, (3) DR. ALEXANDER M. MOOD, OPERATIONS RESEARCH SOCIETY OF AMERICA, (4) DR. C. WEST CHURCHMAN, UNIVERSITY OF CALIFORNIA, AND (5) DR. LAWRENCE STOLUROW, UNIVERSITY OF ILLINOIS. (JC)

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A New Approach to Education's Problems

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Draft of monograph prepared by Center for Instructional Communications, Syracuse University, for U.S. Office of Education.

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(TENTATIVE)

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FOREWORD

In recent years, professional educators have expressed increasing concern about the lack of conclusive and convincing research on the contributions of the newer media of instruction to the teaching-learning process. The National Defense Education Act (NDEA), passed by the United States Congress in 1958, attempted to fill the gap by activating Title VII A which was set up to provide support for a variety of research projects concerned with instructional media and especially the so-called "new media" which include educational television and radio, programed instruction, motion pictures, filmstrips, slides and tape recordings. More than 300 such research studies have been funded and, in addition, the major philanthropic foundations have contributed sizable amounts of money to promote both basic and action research on utilization of the newer media of instruction. Without doubt, these studies have had a salutary effect on American education, but much of the research has had less impact on educational practice than the initiators of the studies had posited. Several factors account for the discrepancy.

First is the extremely high proportion of "no significant difference" studies resulting primarily from the fact that disparate techniques were being compared with media and studies were carried out on non-generalizable samples, some so divergent in character

that replication was virtually impossible. Second is the fragmentation of research studies applied to so many media with such a variety of approaches that no overall conclusions can be drawn. What seems to be needed is a research pattern or design that will attack several major areas within the educational media spectrum rather than try to "cover-the-waterfront" as is now being done. Third is the fact that research usually is done by individuals with relatively small amounts of financial support which permit only minimal investigation of a small segment of a vastly greater problem. Fourth are the restrictions imposed on the researcher by regulations in the National Defense Education Act itself which specify that the initial proposal and its research design must be followed to a conclusion even if new directions are indicated after studies are begun. Fifth, because of fragmentation and non-generalizable samples, most of the studies produce almost no overall effect on either instructional media or education. This may well be due to the fact that few of the studies reported by Title VII have been used by personnel in public education. There have been so few studies that follow a single, forceful line of attack that no real impact can be noticed.

Within the scope of foundation-supported projects, greater success in terms of impact can be noticed. The type of studies produced, however, can be labeled only as one type of action research. The television studies by the Ford Foundation including MPATI (Midwest Program on Airborne Television Instruction) are

excellent examples of the compromise of action research and pure action in an attempt to prove the effectiveness of one of the newer media as a partial solution to the problems of American education.

Finally, the sixth factor accounting for the discrepancy between funds expended and impact of research produced is the inadequacy of traditional research techniques to cope with the tremendous number of variables inherent in any research on the process of education and the weakness of statistical methods in dealing with an adequate appraisal of the long term results of educational innovation.

Members of the Research Commission of the Department of Audio-visual Instruction of the National Education Association were concerned because research on media had failed to achieve its expected potential. In 1963, Commission members felt the time was right for action to be taken to give new directions to media research, accelerate research output, coordinate results, increase financial support and train new researchers in the field. Recognizing that these ends would not be achieved until new and more effective research techniques are available, they requested the United States Office of Education to sponsor a conference to discuss ways of developing "new dimensions for research in educational media" utilizing the systems approach to problem-solving. Authority to conduct such a conference was granted under Title VII B of the NDEA which permits expenditure of federal funds "to disseminate information concerning

the new educational media." The basic assumption that a systems approach to instruction is valid was accepted by conference planners.

Syracuse University was awarded the contract and its Center for Instructional Communications instructed to conduct the conference which was held April 2, 3 and 4, 1964, on the Syracuse campus.

Serving as keynote were five primary papers prepared by eminent authorities in the area of operations research and systems analysis on topics related to the development of a systems approach to research on instruction. The primary authors whose papers are included in the Appendix to this monograph were:

I. Dr. Russell L. Ackoff, at the time of the conference, Director of the Operations Research Group, Division of Organizational Sciences, Case Institute of Technology, and, presently, Director of the Management Science Center and Chairman of the Department of Statistics and Operations Research, Wharton School of Finance and Commerce, University of Pennsylvania.

II. Dr. Carl A. Bennett, Manager, Applied Mathematics, Hanford Atomic Products Operation, General Electric Company.

III. Dr. Alexander M. Mood, President, Operations Research Society of America.

IV. Dr. C. West Churchman, Professor, School of Business

Administration, University of California at Berkeley.

V. Dr. Lawrence Stolurow, Director, Training Research Laboratory, Department of Psychology, University of Illinois.

Invited to participate in the conference were 40 prominent scientists and educators representing the fields of psychology, social science, philosophy, educational administration and instructional media. A list of participants is contained in the Appendix.

As a condition of attending the sessions, each conferee agreed to read in advance and study all five of the primary papers which were distributed several weeks before the meeting. Five from among the group -- one representative from each of the above-mentioned disciplines -- were named to prepare detailed reactions to the original five papers for presentation at the conference. Each was requested to respond from his own particular professional point of view and the remarks formed the basis for much of the discussion during the conference. Authors of the reaction papers which are also included in the Appendix were:

Dr. Hobert Burns, Dean of the College of Education, Hofstra University, educational philosophy.

Dr. Nicholas A. Fattu, Professor and Director of the Institute of Educational Research, Indiana University, educational psychology.

Dr. Peter Muirhead, Assistant Commissioner for Program and Legislative Planning, United States Office of Education, social science.

Dr. Abram VanderMeer, Dean of the College of Education, Pennsylvania State University, instructional media.

Dr. Kenneth Williams, President of Florida Atlantic University, educational administration.

All of the authors were expected to be on hand during the conference to explain, amplify or defend their position and respond to questions submitted by conference participants.

This monograph attempts to provide highlights from the ten papers that were prepared for the conference and to summarize the lively and pertinent discussions that took place during the two-and-a-half days of meetings.

Grateful appreciation is extended to members of the conference Planning Committee (listed in the Appendix) for their assistance and guidance, to the ten authors, to Kenneth Norberg who served as conference moderator, to Paul Witt who summarized the proceedings, to Harold Mitzel and Loran Twyford who reviewed this report, to Donald Ely and Edward Montgomery who gave wise counsel, and to all of the graduate students and members of the staff of the Center for Instructional Communications who provided a multitude of services to assure the smooth operation of the Syracuse conference.

Eugene K. Chandler,
Conference Director

Eleanor C. Taylor,
Editorial Assistant

August 15, 1963

CHAPTER I

Background for a Systems Approach

American education is under fire.

Its critics argue that it fails to meet mid-Twentieth Century needs.

Its dilemma is compounded by increasing amounts of knowledge and increasing numbers of individuals to be educated and re-educated for gainful employment in a technological society.

The problems of education are probably no greater than those facing American government, business and industry; as institutions and organizations expand in size and diversity, they inevitably become more complex. This chapter will examine a problem-solving approach that is widely used by government, business and industry to cope with their ever-increasing complexity of operation.

A hundred years ago, most businesses were managed by their owner who engaged perhaps two or three persons to assist his operation. The majority of Americans lived in small towns or rural areas and government functioned with only a few departments and agencies. Education, when it was publicly provided, consisted of the three R's taught in a one-room schoolhouse by a schoolmaster who was charged with instructing all of the pupils regardless of their age and ability. Only a few students other than the sons of the wealthy continued beyond the basic educational level to prepare for a career of preaching, teaching, medicine or the law.

Life, though rugged physically, was relatively uncomplicated and trial-and-error remedies could solve most problems. Time -- if not money -- was ample and each family was a fairly self-sufficient unit providing for most of its daily needs without outside assistance.

As institutions and organizations grew in size and diversity, and became more complex, functions and duties were divided and sub-divided, again and again. As the parts multiplied, management problems compounded correspondingly until business and industry as well as governmental, educational, religious and charitable institutions became so multiphased and geographically scattered that their physical organization alone grew beyond the ability of the human brain to comprehend. The trial-and-error remedies that solved problems in earlier days were no longer applicable. New techniques were needed to cope with the new complexities.

Such was the situation facing British military leaders when the German air invasion of their island began in 1939. During the two intervening decades since the end of World War I, new technologies had been developed but had not been fully integrated into military tactics and strategies. One of these was radar -- at that time a brand-new discovery. If England was to survive attack, every possible emergency means of defense had to be put into effect immediately. Thus, small teams of research scientists from a variety of disciplines were assigned the task of devising solutions to the urgent problems created by the war.

So successful were the joint efforts of these teams that the technique was quickly adopted by military leaders in the United States, Canada

and France. Much of the success of the Western Allies in combating air and submarine attack during World War II is credited to the work of these interdisciplinary research teams whose efforts came to be known as "operational research" because they usually were assigned to the military executive in charge of operations.

In the United States the work of the teams was called variously "operations analysis," "operations evaluation," "operations research," "systems analysis," "systems evaluation," "systems research," and "management science." Controversy continues among the experts regarding definitions of these terms but operations research* -- abbreviated OR -- seems to be the one most widely used today to describe the technique which was first developed to meet urgent military needs during the early, desperate days of World War II.

At the close of hostilities, it was natural that the new technique -- so successful during wartime that it is credited by some authorities as hastening the end of the conflict by many months -- should be applied to peacetime purposes.

For several reasons, Great Britian was in a position to adapt OR to peaceful use more quickly than the United States. Demilitarization came sooner there because of earlier reduction in defense expenditures, especially expenditures for research. Thus, many OR specialists were released

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* See Glossary. N.B.: All words and terms that are defined in the Glossary of this monograph are underlined the first time they appear in the text.

by the military at about the time the nation was facing a mammoth rebuilding project to repair the devastation from German bombs and rockets. In addition, the Labor Party had come to power and begun nationalization of several major industries and services. With their wartime successes to guide them, British OR specialists put the new technique to work to solve peacetime problems.

In contrast, the United States continued to expand its military operations research program even after the end of hostilities so that on this side of the ocean most of the veteran OR practitioners remained with the military service. American civilian industry, for the most part, returned to its old pre-war methods of functioning.

But, in the meantime, another new technology -- like the operational research technique, born and nurtured during World War II -- was being perfected and readied to make an impact on the American industrial scene. This second technological advance was automation: the replacement of man with a machine as the source of control. It was made possible by the development of the electronic data-processing machine, forerunner of the modern computer.

When this new equipment became commercially available during the early fifties, executives of U.S. business, industry and non-military branches of government began to search for technically trained specialists who could assist in its utilization. Some of the pioneer operational researchers were imported from England. Many American experts were engaged as they were released by the military. Eventually, courses in operations research were developed by institutions of higher learning

and, at present, a number of them offer advanced degrees in the field. (See Appendix)

Today, there are an estimated 10,000 OR specialists at work around the world. They are engaged in projects of long-range planning for cities, regions and nations and are working at executive problem-solving for business and industry as well as military and non-military governmental agencies. An OR specialist may be an outside consultant hired for a specific task or he may be a permanent employee usually at the managerial level.

Even though the technologies of OR and automation are intimately associated,

should be italicized { one must always remember that effective operations research does not depend exclusively on the use of the computer and, conversely, utilization of a computer does not necessarily imply that the techniques of OR are being applied to the solution of a problem.

The technological infants of the forties have become the Samsons of the sixties. They have altered the major problem-solving approaches of government, business and industry in less than a generation. Their success in these fields has led American educators to ask:

should be italicized { What potential do these new technologies have for solving some of the urgent problems in the field of education? And, more particularly for this document, educational media specialists are asking: How can the systems approach, utilizing operations

research and the tools of automation, be applied to develop new dimensions for research that will result in improved instruction in the nation's schools?

Concern over these questions led to the conference that was held April 2-4, 1964, at Syracuse University sponsored by the United States Office of Education.

This monograph is based on material prepared for and presented during that conference which was attended by leading educators and scientists from all over the United States. The chapters that follow will describe the general techniques of conducting operations research, point out some problems and pitfalls that may be encountered along the way and list some successful applications of OR in a variety of fields. Finally, major areas in the field of education -- especially in the domain of instructional media -- where OR may be effectively utilized in problem solving will be suggested.

CHAPTER II

The Techniques of Operations Research

Rather than suggest a specific definition of operations research -- which seems not yet to be defined to the satisfaction of a majority of its practitioners -- let us describe it through Dr. Russell L. Ackoff's enumeration of its three essential characteristics.

According to Dr. Ackoff, OR consists of:

1. Research on problems involving the control of organized (man-machine) systems to provide solutions which best serve the purposes of the organization as a whole,
2. Through the application of scientific method,
3. By interdisciplinary teams.

In an organized system the behavior of any one part ultimately has some effect on every other part. Not all of these effects will be significant, nor even capable of detection, but the researcher will be required to discover the interactions of the parts in order to determine which interactions are significant to the research task at hand. Dr. Ackoff points out that this approach is directly opposed to "cutting a problem down to size" and describes it as a technique of enlarging the concept of the problem to include all of its ramifications.

Dr. Carl A. Bennett details the requirements of a problem that is

suitable to be solved by OR techniques. The problem should be complex. Dr. Bennett emphasizes, with many factors involved in it. These factors consist of constants (unchanging elements) and variables (elements that change from time to time or situation to situation). In either case, they must be capable of being measured and described in quantitative terms because the methods and techniques of OR are applicable only to problems dealing with rational processes for which tests and measures can be designed. The problem should be large enough to be realistic, encompassing within its structure both ultimate goals and feasible solutions in the light of available resources but, at the same time, it must be small enough so that the researcher can obtain a solution in a relatively short time.

The applicability of OR techniques does not depend so much on the size of a problem--how large or how small it is--but on its level of specificity, according to Dr. Alexander Mood who pointed out during conference discussion that, the more general a problem, the more difficult it becomes to apply the techniques successfully. There are some problems at such broad levels that he considers it ridiculous to attempt a formal OR analysis. His conclusion is that the more specific and down-to-earth the problem, the more reasonable it is to utilize the techniques of operations research in its solution.

The application of scientific method implies experimentation. Because organized systems usually cannot be subjected to experimentation in the ordinary sense of trial and error, operations researchers must construct a representation of the system they are studying in

the same way an astronomer constructs a representation of the system he is studying in order to experiment on it. Such representations are called models and, in operations research, usually take the form of mathematical equations. Mathematics, in fact, has been described as the language of the scientific method and, in OR, mathematics provides the language in which the properties of the system being studied can be expressed. Statistics, on the other hand, which has been described as the technology of the scientific method, is used by operations researchers to establish relationships within the model (or representation of the system) and to examine the degree to which these relationships are truly representative of the actual system that is being studied. Operations research, like other research, requires tools for its successful accomplishment and mathematics and statistics serve as its tools--mathematics being used to formulate and solve the model and statistics being used to verify it.

The researchers can experiment freely with their model until they derive a solution to the problem; their experimentation is called simulation. It is here that computers, with their rapid data processing ability are extremely useful to OR practitioners. Vast quantities of data can be combined with a variety of theories and hypotheses and fed into the electronic device which quickly reduces ~~with~~ of the information to equivalent terms that can be correlated and interpreted by the researchers. Through this process, functional relationships can be uncovered ~~and~~ leading to the formulation of new theories and hypotheses which again may be fed to the computer to be analyzed and related to

an ultimate solution to the problem at hand. A major benefit deriving from the use of a computer is the ability to examine a wide range of possible solutions to a problem in a relatively short period of time.

It must be noted, however, that in many cases a solution can be determined merely from the structure of the model without any simulation; that is, deductively by analysis rather than inductively by simulation. In some instances, non-mathematical models have been used successfully. In any event, if the model is a truly good representation of the system being studied, the solution will improve the performance of that system. Therefore, the model must be tested and the solution evaluated by the team of researchers.

If, with the passage of time, significant changes can be expected to occur within the system that will effect its performance, these changes must be detected by the researchers and the solution to the problem controlled by being adjusted as required by the changes. Such control is of great importance when the solution will be translated into a set of rules that will be applied to decisions that are to be repeated and, especially if these repeated decisions are to take place over an extended period of time.

And, finally, the results of the research must be implemented once they are accepted by the decision makers since the ultimate objective of operations research is to improve the performance of the system rather than merely to produce reports. Dr. Ackoff believes that the implementing or final phase of the analysis provides the ultimate test

and evaluation of the research task and offers the researcher the greatest opportunity to improve his own practices.

The third essential characteristic of OR, the interdisciplinary team, is comprised of a number of scientists representing as many fields of study as necessary in order that they may consider and evaluate as wide a range of approaches to a problem as possible. A problem can never be properly described as "a physical problem," "a psychological problem" or "an economic problem," Dr. Ackoff observes. All are problems in the most general sense of the meaning of the word and the various scientific designations represent some possible and different ways of approaching them. Selection of a team that represents as wide a range of interests as are pertinent to the problem under consideration results in a general rather than a specialized treatment of the problem.

The practitioner who will be most successful in conducting operations research, Dr. Bennett believes, will be a generalist rather than a specialist. He will employ, as members of his interdisciplinary team, specialists in such techniques and tools as mathematics, statistics, and computer programing, along with specialists in the subject matter fields pertinent to the OR task at hand. Some other disciplines that might be represented on the team include the behavioral sciences, economics, and philosophy. But always, Dr. Bennett reiterates, it is absolutely essential that one or more members of the team, and perhaps even the entire team, possess the ability to generalize if the OR task is to reach a successful conclusion. A generalist may come from a variety of backgrounds; he may be trained in mathematics or statistics although

neither background is a guarantee of success in operations research. It is possible for a good scientific generalist to develop in any field, Dr. Bennett believes, as long as he understands the cyclic, iterative aspects of the model-building process and the relation between model and subject matter. Ability to use the essential tools he describes as the second most important requirement, followed by expert knowledge of subject matter. This third competency can, of course, be provided by a specialist member of the interdisciplinary team.

With the three essential characteristics of OR assumed -- research on problems involving the control of organized systems, through application of scientific method, by interdisciplinary teams -- Dr. Ackoff suggests six procedural steps to successful accomplishment of an operations research task:

1. Formulating the problem
2. Constructing the model
3. Deriving the solution
4. Testing the model and evaluating the solution
5. Controlling the solution
6. Implementing the solution

He offers the following admonition to anyone attempting an operations research type of analysis:

> Always remember that an OR practitioner is never given anything; he must discover everything for himself. He starts with a great big buzzing confusion from which he tries to formulate a meaningful problem. No one identifies for him the controllable variables or the constraints or the objectives. Determining them constitutes about three-quarters of his task. In short, he is faced with a patient who presents an aggregate of symptoms -- he must do the diagnosis.

During the conference, Dr. Ackoff discussed eight types of problems that he considers suitable for analysis and solution by operations research techniques. They are:

1. Inventory Problems
2. Allocation Problems
3. Queuing or Waiting-Line Problems
4. Sequencing Problems
5. Routing and Network Problems
6. Replacement Problems
7. Search Problems
8. Competitive and Cooperative Problems

1. Inventory Problems

An inventory consists of valuable resources -- such as men, machines, money, material or information -- in a state of idleness. Inventory problems involve one of the following questions:

a. How much of a resource to acquire (through production, purchase or training) when the frequency of acquisition is fixed?

b. How frequently or when to acquire a resource when the quantity is fixed?

c. How much and how frequently to acquire a resource?

These questions present a problem if there are one or more costs that increase with increases in inventory and one or more costs that decrease with increases in inventory. The problem, then, is to find the quantity and/or frequency of acquisition which minimize the sum of these costs.

Among the types of cost which may increase with increasing inventory are storage costs, handling costs, taxes, insurance, spoilage and obsolescence costs. Among costs which may decrease with increasing inventory are costs of setup (preparation of purchase orders or production runs), costs of delay in meeting a requirement or of failure to do so, price (the larger the quantity purchased or produced, the lower may be the unit cost), and the cost of labor stabilization. If one tries to match production facilities to varying demands for a resource, one becomes involved in additional hiring and firing and their associated costs.

Inventory problems arise in a wide variety of contexts. For example, determining how much trained manpower and of what type (e.g., teachers) to have in an organization or in a nation is an inventory problem in which training is analogous to the process of production. How much capital should be kept available for spending (fluid capital)? How many classrooms should a school have and what size should each be? When should schools be built and how large should they be? All problems involving acquisition of educational stores, supplies and equipment are included in this category.

Operations Research has developed a capability of solving a wide variety of inventory problems by use of mathematical analysis. The techniques are known as Inventory Theory. A number of elementary, intermediate and advanced texts devoted exclusively to this subject are available.

2. Allocation Problems

An allocation problem arises when:

a. A set of jobs is to be done,

b. Resources are available for doing some or all of the jobs,

c. Some or all of the jobs can be done in different -- not equally efficient -- ways by using different resources, but,

d. Each job cannot be done in the most efficient way.

The problem is to allocate the resources to the jobs in such a way as to achieve the best overall performance. If more resources are available than required, the allocation must also indicate which resources are to be unused or what jobs are to be added. If fewer resources are available than are required, the allocation must indicate which jobs will go undone or what resources should be added and where they should be added.

Budgeting is an allocation process; so are assigning teachers and students to classes and assigning classes to specific rooms. The distribution of goods from multiple sources of supply to multiple destinations also is an allocation problem.

Mathematical programing is a recently developed set of techniques for solving certain large classes of allocation problems; technical literature in the area is extensive.

3. Queuing or Waiting-Line Problems

A queuing problem arises when:

a. A set of facilities which provide a required service and a set of things (customers) which require service are out of balance (i.e., facilities are idle or customers are waiting), and,

b. There are costs associated with idle facilities (e.g., salaries of unoccupied people or depreciation of unused equipment) and

costs associated with waiting customers (e.g., lost business or delay costs), and,

c. Either the arrival of customers can be controlled (by scheduling) or the amount of facilities available can be controlled, or both.

The problem is to schedule customers and/or provide facilities so that the sum of the cost of providing service and the cost of waiting customers is minimized.

Queuing problems are encountered very frequently. They include: How many secretaries, clerks, duplicating machines, and so on, shall be provided in an office? How many trucks should be included in a delivery fleet? How many parking spaces are necessary at a shopping center or airport? How many docks are needed at a port? How many cashiers or servers are required at a cafeteria, or clerks behind a counter in a store? How many librarians should there be in a library, how many projectors in a school?

Most queuing problems can be solved by the application of probability theory or the techniques of simulation. The more simple problems are handled by analytical techniques and the more complex ones by simulation. Here, too, the technical literature is extensive.

4. Sequencing Problems

In solving queuing problems, one assumes that the order in which waiting customers are selected for service -- the queue discipline -- is known. Some common queue disciplines are "first come, first served," "in order of size" and "alphabetically." Sequencing problems involve determining the order in which waiting tasks should be performed in order to minimize costs

which depend on the time required to complete all of the tasks and the time required to complete each of them (e.g., in relation to promised completion dates or times).

For example, in what sequence should emergency cases in a hospital be treated? In what sequence should special factory production orders be processed? Coordination of a complex set of interdependent activities presents a special kind of sequencing problem for which effective means of solution recently have been developed. These are PERT (Program Evaluation and Review Technique) and Critical Path Method. Planning a curriculum is an example of this special kind of sequencing problem.

Other types of sequencing problems are still difficult to solve because, in general, they require simulation techniques which are complex and expensive.

5. Routing and Network Problems

A network can be described as a set of points connected by a set of lines. The lines can be described by their length (the distance between points), the time required to traverse them, the cost of traversing them, or their capacity (how much they can "carry").

Network problems involve finding one or more routes through a network which meet some criterion concerning distance, time, cost or capacity. For example, a road map is a network and finding the shortest route, in time or distance, or the least costly route, between any pairs of points is a network problem. Or, it may be necessary to find the shortest route through a set of cities, never visiting any city more than once and returning to the

point of origin (the routing problem of a traveling salesman). Other network problems include routing telephone calls and trains. A not-so-obvious network problem arises when a number of different products have to be produced on one assembly line and there is cost involved in changing the line (setup) for each product. Here the points of the network are the products and the lines connecting them have a length that is proportionate to the cost of changing the equipment from the last product (origin) to the next product (destination).

A wide variety of network problems can be solved by mathematical techniques. Many that can't be solved in this way will yield to simulation.

6. Replacement Problems

These problems fall into two classes depending on the nature of the things to be replaced: whether they are degenerating, i.e., with use they become less efficient or more costly to keep efficient, or non-degenerating, i.e., they operate at constant efficiency until they "die" and can no longer be used. Degenerating items are usually, although not necessarily, large expensive items such as buildings, means of transportation, production equipment, audiovisual equipment, and, sometimes, people. Non-degenerating items are usually, but not necessarily, small inexpensive items such as light bulbs, ball-point pen fillers, radio tubes, springs, automobile mufflers and most toys.

The more frequently a degenerating item is replaced, the greater is the amount spent on purchasing equipment -- capital investment -- but the less is the amount spent on maintenance or loss due to inefficient operation.

The problem is to determine when to replace such items in order to minimize the sum of those costs. Such problems can be solved by a variety of mathematical techniques, perhaps the most generally useful is Dynamic Programming.

Non-degenerating items usually are acquired and used in quantity. The cost of replacing each item may exceed its purchase cost, e.g., a light bulb used in a school building or projector, and additional cost may result from its failure to perform, e.g., work or class activity may cease. If items are replaced in groups, the unit cost of replacement is reduced but the number of items used increases. The problem, therefore, is to determine when to make replacements individually and when to replace in groups in order to minimize the sum of the cost of the items, the cost of replacement and the cost of failure.

Most problems of this type can be solved by analysis or simulation.

7. Search Problems

Two types of errors are associated with looking for something: one may not look in the right place which results in sampling error; or, one may fail to see what exists or see something that does not exist which results in observational error. When a fixed amount of time or money is available to conduct a search, increases in the number of observations result in increases in the sample size and decreases in the sampling error, but at the same time, reduce the amount of time or money allocated to each observation, thus increasing observational error.

A search problem consists of determining either:

a. How many and what observations must be made to minimize the costs of error when the available resources are fixed, or,

b. How many resources should be used in order to minimize the sum of their cost and the costs of error?

Geological exploration for oil, coal or metallic ores, inspection and quality control procedures, auditing and accounting, and screening chemical compounds for pharmaceutical properties are examples of processes which may involve search problems. In addition, there are many military applications including hunting for submarines as well as land and sea mines. The "literature" search should not be overlooked as an example of this type of problem.

An inverted search problem exists when the thing looked for is controlled rather than the method of search. Some examples of this type of search are the design of a filing system or other information-storage system such as a library, or the placement of goods in a department store or supermarket.

Many types of mathematics -- including geometry -- may be utilized in solving search problems but the one most generally useful in this area is Statistical Decision Theory.

C. Competitive and Cooperative Problems

These problems arise whenever a decision by one party, A, evokes a decision by at least one other party, B, which affects the outcome of A's choice. B's action may enhance A's decision (cooperation) or it may detract from it (conflict or competition). The study of decision-making under any condition of interacting decision-making usually falls in this category.

Problems involving business cooperation, or collusion, or military conflict, fall in this class as do most aspects of the student-teacher relationship. A great deal of this type of competition and cooperation also exists between schools and school systems.

Game Theory provides a conceptual framework within which problems such as these can be formulated in mathematical terms. It does not, however, provide a way for solving most of them and Statistical Decision Theory generally is required to arrive at a solution.

Most of the problems that managers or administrators of large organized systems are called upon to solve can be analyzed into one of these categories or into some combination of the eight types of problems. Knowledge of the theories and techniques applicable to their solution, therefore, is an essential part of an OR practitioner's equipment.

Only a few suggestions concerning educational applications have been listed; many more should be readily apparent to persons who are confronted with a variety of complex problems during the course of their actual work in the field.

The chapter that follows will offer some specific suggestions for the novice practitioner and focus attention on some of the difficulties that educators may encounter in actually applying the techniques of operations research to a scientific appraisal of instructional media.

CHAPTER III

Some Considerations

To illustrate some of the problems associated with the application of a systems approach which would include an operations research analysis, Dr. Alexander M. Mood in his paper hypothesizes an OR task involving the use of instructional media in a specific situation. Dr. Mood asks: To what extent, if any, should motion pictures be used in a high school biology class?

Proceeding step-by-step, he first questions whether or not the problem is suited to analysis by OR techniques. To answer the query, he identifies all variables that normally would have to be considered in setting up a model for solution of the problem and then appraises the degree to which each can be measured--either quantitatively (numerically) or qualitatively (judgmentally).

In many cases, Dr. Mood notes, there will be so many appraisals relying so completely on human estimate that a quantitative analysis by OR techniques would be too forced to be effective. In such instances, the solution of the problem is largely a matter of judgment and is better arrived at through qualitative analysis rather than through OR's quantitative approach. When this occurs, however, it is sometimes possible for the practitioner to isolate some portion of the larger problem that

will lend itself to quantitative analysis and then apply OR techniques to the solution of this smaller part, he points out.

Once it is resolved that a problem is suitable for an operations research approach, several additional determinations must be made before the analysis can get underway. According to Dr. Mood, the practitioner must:

1. Decide the scope of the analysis, (What shall be included and what shall be omitted?)
2. Consider the economic factors involved, (Some kind of costs usually must be taken into account.)
3. Define the relations between variables, (This includes specific definitions of the functional forms that enter into the relations.)
4. Fix the values of the parameters, (These are the constant or non-variable elements in the functions and equations.) and,
5. Specify the criterion or expressed goal of the analysis. (The criterion is the thing that the analyst is trying to optimize and it must be specified carefully, with mathematical precision.)

Dr. Mood observes that the criterion nearly always is the most elusive part of the entire analysis and rarely seems to be exactly right even after it has been carefully specified. To avoid some of the problems frequently involved in determining the goal or criterion of an OR task, he suggests a rule of thumb: The goal should be expressed in terms about one level above the problem being investigated to assure

that it will fit the immediate context of the task at hand. To illustrate, he refers to his original problem concerning use of motion pictures in a high school biology class and advises that, in this instance, the criterion should attempt to shed some light on the advisability of using films in teaching biology and not concern itself with such general goals as maximizing the amount of biology learned or describing the fundamental aims of education.

Referring to such far-afield activity as a problem of philosophical pursuit, Dr. Mood describes it as "getting off into a thicket" and emphasizes that the criterion must always be a function of the variables involved in the particular analysis. Indeed, it is because the criterion depends on them that some of the variables are included in the model in the first place, he points out. The others are included simply because they are entangled with the required variables.

A final bit of advice regarding criterion and goals is offered by Dr. Mood who warns that, generally, multiple criteria (two or more goals to be attained simultaneously) must be combined into a single criterion before an operations research task can be carried out successfully.

Despite the difficulties that may be encountered in pursuing an OR-type quantitative analysis rather than solving a problem by judgmental appraisal, Dr. Mood considers the results well worth the effort. He admits that the role of judgment looms large even in an OR analysis, particularly in the human estimate involved in delineating the problem in the first place, determining its scope, selecting the criterion and

including, excluding and aggregating various factors and functions during the process. He emphasizes, however, that the alternative--a purely qualitative analysis--relies completely on judgment and is better described as an art than a science.

Dr. C. West Churchman points out in his paper that discussions concerning problem solving often bog down in unresolvable philosophical debates and proffers two such diametrically opposed points of view--the necessity of studying the parts of a system in order to be able to understand the whole system, versus the necessity of understanding the broad concept of a system before attempting to identify or, much less, to improve any of its parts.

Relating these two approaches to systems in general and educational systems in particular and refusing to become embroiled in debate, Dr. Churchman suggests an alternative approach which he designates "<u>housekeeping</u>." He defines it as the principle of straightening out an existing system by leaving the goals invariant while working only on the parts that are out of order. Paraphrased it is: When you see a mess, clean it up! The great value of this approach, he believes, is that it does not raise broad, unanswerable questions about long-term goals but rather assumes present policy as a "given" and proceeds to determine if it is being carried out effectively. It is a middle-of-the-road regard for "parts" and "wholes" with neither having precedence over the other. Agreeing with the philosophy that one should begin with the parts but, at the same time, disagreeing with the notion that thinking about the whole is an earned privilege acquired only after much

diligent study, he suggests action as a proper beginning in solving problems. The recommended action constitutes housekeeping.

To illustrate the practicality of the housekeeping approach, Dr. Churchman points out that very few of the large systems inhabited by humans are understood by anybody. Yet, people live and work in these systems every day, coping with problems as they occur by studying the part that is malfunctioning and attempting to redesign it to improve its performance.

Three types of irrational procedures (malfunctions) that may exist within a system which need to be identified so they can be eliminated are cited by Dr. Churchman as appropriate for the application of his housekeeping principle. Listed in increasing levels of complexity, they are:

1. Procedures that are clearly detrimental, (No one in the system really wants them but no one has had time to do anything about them. An outside observer often can see how to correct this type of defect and finds no serious difficulty getting his recommendations accepted.)
2. Procedures that may be the result of bad bookkeeping, poor office management or mis-assignment of personnel, (Routine techniques of industrial engineering often suggest improved design which may gain acceptance and cause no disturbance to the entire system.) and,
3. Procedures that appear to be carried out inadequately in the light of advanced technology. (At this third and most complex

level, OR techniques should be utilized because changes in procedure are apt to disturb the whole system.)

Some of the ramifications involved in working at this third level are described by Dr. Churchman in a discussion of programed instruction which he views as an attempt to solve a housekeeping problem in the field of education. Defining instruction as the activity ordinarily centered in the classroom, he points out that programed media have been introduced in an attempt to relieve teachers of some of their more routine instructional tasks, particularly where material is highly formalized. If this replacement of teacher with programed material is a proper application of housekeeping then it should not be necessary to delve into the goals of the course, or the goals of education in general, according to the definition of the housekeeping principle. But, Dr. Churchman asks, what if the use of programed media for instructional purposes results in the teacher having to spend additional time and effort to build and maintain student motivation? Does the cost justify the return? And here he amends his paraphrased statement of principle to read: If you see a mess, clean it up, unless the net return to the whole system seems too small! Side effect problems must always be considered, he points out, and, if they appear too great, the housekeeping approach should not be applied.

A second principle suggested by Dr. Churchman requires a method of examining the whole system. It is based on the premise that every part of a system has two fundamental properties:

1. Its benefit to the whole system, and,

2. The cost, or price, of its attaining a given level of benefit.

Neither benefit nor cost is what it appears to be on the surface because each exists only in relation to its effect on the whole. These effects are difficult to compare because usually they are measured in dissimilar units. Therefore, Dr. Churchman's second principle becomes: Benefits and costs of a part of a system cannot be determined without knowing how the whole system works. In this setting, lost opportunities which may involve great cost to the whole system become equally as important as dollar values of the parts.

To determine benefits and costs of a part more accurately, he suggests a decomposition model of the system or organization that is being studied in order to calculate optimal strategies even when a thousand or more variables are involved. Retaining the advantages of centralized planning and yet allowing decentralized control, such a model in a sense permits the entire system to think through a plan before acting on it with each part competing against each other part for scarce resources. Dr. Churchman considers this decomposition model approach preferable to the technique of simulation which he describes as an expensive procedure that produces confusing results except when an explicit model is being tested.

Because understanding the whole system is a long and tedious task at best, Dr. Churchman harks back to his housekeeping principle as the most acceptable and expedient approach to problem solving. His advice to all

who believe that operations research can help solve education's problems is that they get to work as soon as possible -- look for irrationalities, estimate their seriousness and judge the gains that may be expected from eliminating them. He further suggests that researchers take great care in recording all of their doubts as they proceed to determine how each part fits into the whole system but he strongly urges them to resist every temptation to wait until doubts are resolved before proceeding. In short, begin immediately and continue determinedly, he admonishes.

Dr. Ackoff advises practitioners not to become enamoured with techniques and forget that each problem has its own unique aspects and that it is not advisable to generalize from problem to problem. Certain practical limitations -- constraints of money and/or manpower -- always exist and combine to produce a solution of a problem that is at best an approximation. Pointing out that OR is no panacea, Dr. Ackoff predicts that the quality of the results obtained by applying OR techniques to the problems of education will be no greater than the quality of the operations researchers who are put to work on the problems. Even the best of practitioners will require patient support and aid over a substantial period of time if success is to be achieved.

Conference participants foresee a number of practical problems that may be encountered when OR techniques are applied to research on instructional media. Some difficulties they anticipate are:

1. Defining an educational system
2. Delineating boundaries of sub- ystems

3. Identifying variables
4. Eliminating ambiguity of terms
5. Agreeing on educational objectives
6. Determining quantitative measures of educational objectives
7. Describing the basic process of learning
8. Formulating a suitable model
9. Understanding the philosophical and moral implications
10. Acquiring precise descriptions of actual teaching-learning processes
11. Developing new OR techniques especially suited to educational research
12. Training education-oriented OR practitioners
13. Relating research projects to each other
14. Implementing results of research
15. Easing funding restrictions to permit greater freedom of experimentation.

The chapter that follows details some of the successful applications of the techniques of operations research in the field of education.

CHAPTER IV

Applications in Education

Mention was made in Chapter I of OR's many successes -- in military victories during World War II and peacetime achievements at the close of hostilities.

Although its application in the field of education has not been so widespread, operations research and the systems approach are being utilized in attempts to solve some specific problems of educational institutions, both immediate and long-range.

OR has been particularly useful in the solution of problems related to such operating procedures as purchasing and storing school supplies and equipment, scheduling students, faculty, classes, classrooms and examinations, record keeping, organizing and staffing library facilities, prescribing bus routes, and operating cafeterias and parking lots. Applications to long-range educational problems include forecasting future enrollments -- in general as well as for individual colleges or departments -- in order to determine ultimate requirements of physical facilities as well as faculties.

Even though a complete systems approach has not been widely applied to research on problems associated with the instructional domain of education, several projects that have utilized the approach in some degree are described in this chapter. Three more specific studies currently being carried out under NDEA grants are reported in Chapter V.

In most instances, however, the research method is not the typical OR approach outlined in Chapter II but an individualized technique using one or more aspects of the classic example.

Dr. Lawrence Stolurow in his paper proposes that instructional media have two roles to play in the systems approach to research on instruction: first, media serve as instruments or tools of research on the instructional process and, second, they serve as integral implements of the instructional process itself.

In their role as tools of research, they provide the means to observe the process of instruction in action in ways not possible before. One class of media, which includes tapes, films, and kinescope recordings, provides permanent replicas of the instructional process which may be examined and re-examined. This class of reproducible media, plus self-instruction programs, have an additional advantage of being able to preserve perfectly both instructional content and method of presentation so that repeated administrations involve no changes in variables.

On the other hand, variables can easily be introduced and controlled for purposes of experimentation when desired. According to Dr. Stolurow, the new media, in their role of research tools, provide a genuine laboratory facility which has never been available in the field of education before. Studies can be replicated, variables specified and controlled, and the whole process recorded in permanent form for re-examination as desired.

An advantage associated with media's other role as an implement of the instructional system is cited by Dr. Stolurow who points out that use of media demands a more explicit and complete conception of the

teaching function than is required when a live teacher presents material. This need has forced efforts in the direction of more formalized descriptions of the process of instruction and, here again, media have been used to arrive at practical and scientific solutions

As an example, he cites the technique developed by Kersh at the University of Oregon which utilizes filmed sequences to provide simulated classroom experience for teacher-trainees. Realistic scenes of actual classroom problems are projected life-size on a screen. At the crucial moment when teacher judgment is necessary to control the situation, the film is stopped and the trainee required to decide a course of action. When the decision is made, the film proceeds, indicating the pupil response that would occur as a result of the particular action. Dr. Stolurow predicts a much wider use of similar, and even more sophisticated, techniques in the future.

In his paper, Dr. Ackoff describes a somewhat similar utilization of operational gaming in a project currently underway at Case Institute of Technology. Working with computer-simulated systems, graduate students are given the opportunity in the classroom to develop their ability to identify, diagnose, formulate and ultimately solve problems in the area of educational research. Another instructional application of an OR technique mentioned by Dr. Ackoff is the assignment of students to research teams -- in experiments at Johns Hopkins University and at Case Institute -- in order to stimulate greater development of their creative capabilities and sense of involvement in problems. Results so far, he says

appear to be strikingly successful.

A. W. VanderMeer, reacting to the primary papers from the point of view of a media specialist, told conference participants that the systems approach -- as a new and broad way of looking at problems -- holds great promise for educational research in general and media research in particular. Traditional research, and especially that involving media, in his opinion, contains too many examples of investigations in which problems have been defined too narrowly and, as a result, relevant factors and variables which might be responsible for significant differences in results have not been considered by the investigator.

The purpose of research on instructional media, Dr. VanderMeer believes, is to improve the contribution media can make toward the achievement of educational objectives. As research studies proceed, it sometimes becomes evident that certain media have the potential to affect a wider sphere than is being investigated -- perhaps even the entire educational system. It would seem to follow, he reasons, that the systems approach has implications for research on instructional media in contexts ranging from studies related to a specific medium all the way up to studies related to the influence of a wide range of media on an educational system and its organization.

Dr. VanderMeer cites several instances where at least a part of the OR approach already has produced some successful results in media research.

The procedure of defining all of the influential (or potentially influential) factors as a step in the research process proved valuable to him

in a recent study designed to improve the effectivenwss of a science filmstrip aimed at developing factual and conceptual knowledge in elementary and secondary school students. His approach was a thorough analysis of the filmstrip, frame by frame, in order to eliminate all irrelevant details and focus more attention on pertinent knowledge. The careful scrutiny resulted in a revised filmstrip that was capable of communicating the desired facts and concepts far more successfully than the original.

In another study designed to improve the effectiveness of instructional motion pictures, he applied the systems-oriented approach of examining each of the parts in relation to each other as well as in relation to the whole. Such attention to relationships produced a film that was better able to convey curricular information and also suggested some rules for increasing the effectiveness of instructional films in general by paying attention to such relationships.

These two studies of Dr. VanderMeer's involved research conducted on a single medium but he predicts that the techniques of operations research in the future will be applied to uncover relationships between and among a variety of media as they are combined in sequence to achieve the instructional objectives of a teaching unit, a course, or an entire curriculum. The OR approach, he believes, by requiring identification of relevant factors -- both inside and outside the media -- will result in awareness of interactions hitherto unrecognized. He expects great research contributions from the activities of an interdisciplinary team

as its members apply their specialized information and outlooks to a scientific study of instructional systems and curriculum development.

And, finally, he foresees exciting results occurring from the application of simulation techniques to a variety of models of school organizations that will run the gamut from the status quo to an instructional system comprised of two-way television sets and equipment for computer-based programed instruction located in the home. This last possibility, Dr. VanderMeer admits, would involve some careful examination of values and a redefinition of the school as a social institution.

In his report to the conference from the point of view of an educational psychologist, Dr. Nicholas Fattu joined in acclaiming the application of a systems approach to research on instructional problems and described a number of instances within his experience where the new strategy has produced significant results. Pointing out that a good deal more statistical information is available concerning the performance of ballplayers and race horses than students in school, he suggested that the reason might be the lack of a common denominator for expressing results — a value comparable to the economist's medium of exchange, money. Dr. Fattu believes that such a common measure of value for education is absolutely essential if OR techniques are to be applied successfully and suggests that "achievement of students" be designated the denominator. He defines achievement as performance on standardized tests that are designed to measure the entire domain of cognitive accomplishment from simple rote learning to synthesis and evaluation. Currently,

he is engaged in a research project supported by the NDEA that is investigating the relationships of trade-off functions between such learning dimensions as aptitude and level of student involvement (opportunity to learn). When such exchange values are established, Dr. Fattu predicts, it will be possible to state combinations of units of aptitude and units of opportunity that will produce a specified level of achievement. Such trade-off functions, he believes, will be of great value to educators who must weigh a series of alternatives to arrive at decisions affecting instruction.

A technique of the systems approach that is especially valuable for instructional purposes, according to Dr. Fattu, is simulation, and especially non-numerical computer simulation which offers an opportunity to acquire a large amount of experience in making decisions and observing their consequences in a short period of time. It is the old-fashioned trial-and-error approach without the disadvantage of time lag. Experiments with computer simulation, he says, have shed new light on some old assumptions about intuitive or creative judgment which is sometimes described as logical analysis.

He describes a study by Kleinmuntz that compares the efficiency of a computer with that of a clinician in diagnosing patients' problems. Results indicate that a computer can yield basic diagnostic judgments just as successfully as a clinician when it is precisely programed toward such a goal. Two practical observations ensue: use of a computer forces the programer to be extremely precise and reveals gaps of knowledge that

otherwise might continue unrecognized and, once a judgment process is standardized and successfully programed, the computer can assist in producing accurate judgments that previously were considered the exclusive domain of logical analysis.

Dr. Fattu believes that these assumptions can be transferred to the field of education and cites another project in which he is engaged which is attempting to determine such an application. The purpose of the study is to identify the problem solving processes (decisions) of teachers as they prepare to introduce new subject matter to students. After observing their performance in integrating content with objectives and arranging instructional sequences, the researchers presented the subjects with a teaching error and proceeded to probe persistently for alternative responses to the question, "What can be done to correct the error?" A great deal of empirical data concerning the repertoire of available solutions has been collected, suggesting that many teacher decisions usually considered intuitive or creative can be precisely described and eventually controlled.

The ultimate solution to many of education's problems, Dr. Fattu predicts, lies in finding new ways to relate and unify large numbers of relatively trivial propositions that are constantly interacting to produce observable effects on the teaching-learning process. He considers the systems approach ideally suited to accomplish successful research study of these complex interactions and expects that it will produce new insights that have never been possible before. The first step must

be a detailed description of the complete sequence of operation of the instructional process and it is here, he believes, that practicing teachers can be of great help to researchers. When such protocols (precise descriptions) are available they will serve as basic data for the OR practitioner.

Three specific studies presently underway which involve the application of a systems approach to the solution of some of education's problems are detailed in the following chapter.

CHAPTER V

Projects in Progress

Primary purpose of the Syracuse conference was to consider ways the systems approach can assist persons conducting research on the use of instructional media in education. Three conference delegates are already involved in such studies under the auspices of USOE's Title VII. The three--John Barson, John Cogswell and Arnold Roe--described their projects to participants and reported progress to date.

PROJECT I

Dr. Barson's project, being conducted at Michigan State University is titled "A Procedural and Cost Analysis Study of Media in Instructional Systems Development."

Purpose

Its objectives are:

1. A review and evaluation of previous and present instructional systems at Michigan State.
2. A design of methods for measuring costs associated with instructional systems as well as the development of sound budgetary planning for using educational media at the university level.
3. The development of hypothetical models of instructional systems for higher education and a determination of their relative merits, and,

4. A report of the information derived from the study.

Personnel

Project personnel at Michigan State consists of two teams:

1. A team from the Provost's Office comprised of representatives from the College of Education and the Audio Visual Center
2. A team from the College of Business Administration, and,
3. An Advisory Committee

Procedure

The team representing the Provost's Office is in charge of examining and analyzing the procedural developments of instructional systems and the Business Administration team is assigned the tasks of handling cost analysis. Both teams report to the Advisory Committee which supervises activities and interprets data.

Progress

The key term--instructional system--was defined by the groups as a set of procedures whereby courses, or learning experiences, are developed and eventually put into action in behalf of the university. Decisions, arrived at as a person faces an instructional problem and then proceeds to solve it, were designated the primary data to be studied by the team examining the procedural development of instructional systems. The researchers then set a threefold task:

1. The isolation of as many decisions as possible
2. The precise identification of these decisions, and,
3. A determination of the sequence in which such decisions normally occur.

Results indicate that certain decisions are made very early in the sequence, others are arrived at much later, including those relating to the means of instruction. The selection of instructional media however, appears to be unrelated to any scientific research. The evidence does seem to point to the fact though, that there must be orderliness in instruction if successful results are to be assured.

From the data, procedures which appear to have universal usability are being combined to set up a sequence (a hypothetical model) that will assist instructors in developing a course of instruction. The next step will include testing the model through simulation by calling in people who are normally responsible for the development of courses of instruction and observing them as they attempt to solve a teaching-learning problem by following the prescribed set of procedures. Later, a revised model will be field tested in various areas of the university and careful measurement made of the variable effects of different instructors, different media specialists and advise- and different subject matters, with special note of the contrast between so-called discrete bodies of knowledge such as engineering and those with less formalized content such as literature. The ultimate result will be the development of a set of procedures which will be available to college and university personnel who are charged with setting up instructional systems that will utilize media to the best advantage. Some practical aspects that the researchers will consider in their planning are: increasing numbers of students, expanding bodies of knowledge, greater sophistication of faculty as well as greater gulf between faculty and

students, more complex communication problems resulting from lack of feedback in large classrooms, more widespread use of standardized courses, and, finally, faculty hostility to change coupled with faculty dis-ease at the presence of media in the classroom.

Because of time and money limitations, the Michigan State study will include no evaluation of the efficiency or effectiveness of the instructional systems which the researchers feel can be adequately measured only by a longitudinal study. When the Provost's Office team completes its analysis of instructional procedures, the team from the College of Business Administration will conclude its analysis to determine associated costs and suggest realistic budgetary plans.

PROJECT II

The second conference participant to present a progress report was John Cogswell of System Development Corporation who is engaged in a two-and-a-half year Title VII A project which he describes as not committed to the usual restraints of experimental design but free to pursue a variety of lines in a variety of directions.

Purpose

Begun in the summer of 1963, its prime purpose is to study the applicability of system analysis techniques and computer simulation to the school organization. It is concerned with the general problem of the organizational structure of a secondary school system as it is effected by the use of new instructional media. The researchres hopes that techniques will be developed during the project that will alleviate some of the complex problems that are expected to result from widespread

adoption of the new media for instructional purposes.

Procedure

Members of the project staff at SDC contacted Departments of Education of the fifty states to determine which high schools in the United States are utilizing the new media in any large-scale way. Their survey uncovered 20[illegible] innovating high schools and discovered that electronic learning laboratories are the most popular innovation, with team teaching placing second. Third in degree of utilization was programed learning although many comments were encountered concerning the inadequacy of the program material presently available. Five schools are being selected and will be analyzed intensively through a systems approach. The first step will be a descriptive study that will concentrate on the instructional aspects of the school organization. Secondly, five separate, descriptive flow diagrams will be designed that will depict the actual sequence of events and relationships between events that affect the instructional program in each of the five schools. Standardized symbols selected for the diagrams are: small boxes representing queues or buffers, large rectangles representing activities and diamond shapes representing the splits or decision points. Such pictorial descriptions, it is anticipated, will force consideration of some logical alternatives that might be overlooked in a purely verbal description of events and relationships. A model of each school organization will be devised so that simulation can be performed and design changes introduced in order to study the effects of these changes on the system. Initial simulations will be performed with no limitation on resources in order to determine the ideal operation when restrictions of reality such as time delays and non-academic

activities do not have to be considered. Later, realistic limitations of human and fiscal resources will be imposed and new simulations performed. The actual progress of a student through the total school year will be simulated and observations made of his progress and problems at various points along the way.

Progress

The Continuous Progress School at Brigham Young University is one of the five institutions selected for intensive analysis. Instructional time there is distributed about 40 per cent to individual study and between 40 and 50 per cent to work in study carrels where each student proceeds with programed materials until he completes a unit and is ready to be tested. At the testing room which operates full-time, he completes a test which is scored immediately. If results are satisfactory, the student proceeds to the next unit; if results are unsatisfactory, remedial work is assigned. Because more than one teacher is involved with each student, the school has encountered a problem in keeping track of his progress. Members of the project staff at SDC are working out a detailed information-processing system that will combine a student's test results with information from various teachers as well as information from the materials center where the student checks out his assignments. All of this information will be compared with an ideal criterion to produce an individual expectancy score for each student that will indicate the level at which he can be expected to perform. The score will serve as a standard for comparison with actual performance. Whenever a student operates below his expectancy score, the information processing system will produce information that will alert the people who can provide him with the assistance he needs.

Actual field testing of techniques will not be possible as a part of the SDC project but personnel anticipate three fairly specific results:

(1) New application of information-processing techniques that will facilitate more widespread use of instructional media in secondary schools,

(2) Innovations in the utilization of physical space in the schools, and,

(3) Awareness of implications of changes in student behavior that may be expected to result from widespread use of the new instructional media.

PROJECT III

The third and final report to conference delegates concerning a Title VII project in progress was presented by Arnold Roe of the University of California. Like Dr. Cogswell, he emphasized that there had been no restrictions from the Office of Education as changes occurred in stated objectives and directions during the three-and-a-half years the study had been underway.

Purpose

The project originally was undertaken to look ahead some years to the basic components of a future automated teaching system -- one in which the lock-step is broken and students are handled on an individual basis through computerized information-processing techniques. As stated above, objectives have been revised as research has progressed.

Procedure

Early experimentation with programed instruction by members of the University of California staff working on the project led them to the assumption that problems of human behavior involved in the teaching-learning process are too complex to be solved in the immediate future by a simple set of laws or principles. They also agreed that the experimental approach to research which the behavioral scientists borrowed from the physical scientists is probably not appropriate for research on behavorial problems. In short, members of the staff concluded early in their investigation that new research techniques must be devised if education's problems are to be solved.

Progress

As a beginning, the researchers decided to postulate an automated teaching system that would not depend on known laws of learning but would concern itself with making the original system a better system. Reaching the goal would require an adaptive system that would permit learning about the teaching-learning process at the same time teaching and learning are taking place. The alternative -- an artificial situation where students serve as experimental subjects outside a real-life context -- was discarded because of the difficulty of measuring results or controlling variables. An essential ingredient of the adaptive teaching-learning system would be capability of handling each student as an individual.

The next step of the California researchers was to designate a criterion by answering, "What are we going to measure and what are we trying to improve?" Certainly it was not test grades, nor achievement scores,

nor amount of time spent in learning, nor even a combination of performance and time. But rather, they decided, they wanted to measure the impact of an educational program -- the influence and effect of the total learning experience on the subsequent lifetime behavior of an individual as it differs from that of a person who does not have the same educational experience. Such a difference is hard to quantify but the researchers selected as a measure the economic value which is represented by the productivity of an individual (his contribution to the gross national product) during his life subsequent to his education. They stated this economic value in dollar earnings and selected career engineers for the study because income dat for the profession are available for the past 30 years. Correcting for changes in dollar purchasing power and utilizing discounting factors, it was possible to project the figures to determine lifetime earnings of students currently in engineering school with an estimated error of no more than plus or minus 5 per cent.

Once these and other projections became available, the researchers compared them with lifetime earnings of hypothetical engineers who might attain the same level of performance with only three years of professional training rather than the traditional four. Some startling possibilities are suggested by Dr. Roe's figures which indicate that society could afford to allocate up to $15,000 per year for each of three years professional training -- as opposed to the actual present average of $2,000 annually for each of the four years -- to educate an engineer in the shorter period with the same net return to society. According to the University of California study, total lifetime earnings and contribution to the gross national product would be identical in either case.

Such economic value comparisons suggest to the researchers a whole gamut of possible applications toward solution of some of education's most pressing problems.

It is outside the scope of the project to compare levels of performance resulting from either the four-year or three-year training periods for engineers. Dr. Roe pointed out, however, that some 120 correlational studies that have attempted to relate performance in school and subsequent life performance have generally concluded that no such correlation exists.

Because the studies described in this chapter are still underway, no conclusive assumptions are made by the researchers at this time. The three projects stand, however, as examples of the variety of ways that the systems approach and the techniques of operations research can be applied in an attempt to solve some of the myriad problems facing education today.

CHAPTER VI

Philosophical Implications of a Systems Approach

Despite the statement in the official contract that the Syracuse conference would accept the assumption that a systems approach is valid and thus avoid discussion of philosophical involvements, a number of participants expressed serious concern about the moral implications of its application to education.

Dr. Hobart Burns expressed such a view in reacting to the primary papers from the point of view of a philosopher of education. Quoting each of the five authors, he pointed out that all seem to agree that operations research functions best, if not exclusively, in analyzing systems where the end product is objective, measurable and quantifiable. To Dr. Burns this presents a dilemma since, in the last few thousand years, educationists have not been able to agree on the necessary ingredients of a successful education, let alone agree on ends that can be quantified. In his opinion, it is impossible to alter the means of education -- the process of instruction -- without affecting the ends -- the educational outcomes. If a systems approach is to be applied to education, he pleads that the "means technologists" be more than mere mechanics, and as sophisticated in their philosophy of education as they are in their technology of research. Such a combination of talents, Dr. Burns believes, will help to assure that ends will be attended to as means are altered.

Similar concern for philosophical implications was expressed by other participants who question the advisability of submitting such a highly humanized activity as education to stark, quantitative measure. Some suggest that ultimate harm may befall the individual as the result of too much emphasis on numerical values to the detriment of moral values.

Dr. Bennett, who points out in his paper that OR is applicable only to processes for which tests and measures can be designed, does not foresee any grave moral hazards involved in applying the technique to education. In fact, he considers the moral aspect to be equally important in the fields of biology, medicine and industrial relations as well as in problems dealing with radiation and materials development in the atomic field -- all areas where operations research has been applied with success. Education's highly human aspect does not imply a unique inability to utilize OR successfully, nor, on the other hand, does it suggest a unique ability to use it. Dr. Bennett suggests, however, that anyone attempting to conduct operations research on instructional media faces a major problem in describing, in quantitative terms, the systems to be studied and the task to be accomplished.

Evidence that the human aspect cannot be overlooked in an OR analysis is offered by Dr. Churchman who describes a project with which he was once concerned: a study designed to expedite accounting procedures used by railroads. Using sampling theory, it was possible for the researchers to propose steps that would eliminate some of the vast amount of paper work without any reduction in the flow of information. Accomplishing this, however, would involve reducing both the number of jobs

and the amount of managerial responsibility. As a result, the solution -- even though it achieved its goal -- was never accepted nor put into practice.

Discounting any possible moral threat from the application of operations research, Dr. Ackoff holds the opinion that the new technique -- and particularly the aspect of model building -- offers exciting possibilities for exploring the implications of a number of different values in the field of education. During conference discussion, he cited a World War II application of OR that sought to estimate trade-off values between the lives of American airmen and damage to enemy targets resulting from air attack. The goal was to determine the maximum amount that could possibly be spent on preserving a human life in time of war.

First, it was necessary to discover the answer to the question: "How much is a human life worth?" If the correct answer is "infinitely valuable" (the first answer given), the OR study of the problem would have been complete and the solution would be to surrender. Necessarily, some dollar value had to be determined. Models were constructed and eventually the value figure of $200,000 per American airman was arrived at. The sum proved to be identical to the amount each member of the American armed forces could be expected to contribute to the gross national product during his working life. When similar analysis techniques were applied to Japan's military forces, the figure was $18,000 per man. With monetary values equated, the amount proved to be a Japanese serviceman's expected life contribution to his country's gross national product. The model,

in these instances, was successful in revealing, exploring and ultimately justifying a very important human value.

Even though unweighted dollars were used as the unit of measure in this wartime application, Dr. Ackoff points out that usually utility units, rather than dollars, are used -- either implicitly or explicitly -- as the major metric of operations research. Dollars are used as the intermediate scale from which other values are converted for the simple reason that, in our culture, most things can be translated one way or another into dollar values. In his opinion, no accurate measures of educational effectiveness can be developed until explicit and operationally meaningful definitions of educational values and objectives become available. It is here, he believes that the techniques of operations research can make a significant contribution to the advancement of instructional media research by identifying these values and establishing these objectives.

One of Dr. Ackoff's studies in the area of education that was particularly useful in identifying values and establishing objectives was cited by him during the conference. A college set out to prepare a ten-year plan that would consider its future physical plant, projected enrollment, faculty salaries, curriculum, faculty-student ratio, teaching faculty versus research faculty ratio, and size of classes. The process of evaluating existing policies in order to reach agreement on preferred ones provided great insight into value questions that had never been considered before. It was discovered that, at this particular institution, it cost thirteen times more to educate an electrical engineer than it cost to educate a mechanical engineer,

raising the question, "Is it worth it?" The act of bringing value judgments to the surface by OR analysis, in Dr. Ackoff's opinion, is extremely worthwhile and results in a conscious formulation of policies that take into consideration the values that are already in existence even though they may never have been precisely defined.

Taking issue with critics who condemn OR's quantitative approach to human problems, Dr. Ackoff predicts that the application of the technique to instructional systems will produce definitions of the goals that education is currently pursuing and suggest ways that they may be pursued more effectively. Explaining that operations research is not technology-oriented in the sense that ends are prescribed and concern is only with means, he confesses that in twenty years of OR experience, he has never encountered a single enterprise -- industrial, educational or otherwise -- whose management is precisely aware of its goals. In fact, one of his most difficult OR assignments was to determine what the corporate goals of one of America's major industries ought to be. Surprisingly to some, he comments, profit is not industry's prime goal.

Discovering the goals people do have as opposed to the goals they ought to have is important to the OR practitioner because, until the former -- the implicit objectives -- are made clear, there is very little chance of arriving at the latter -- the preferred goals. One of the best methods the practitioner has for securing this information, Dr. Ackoff advises, is to confront the decision makers with sets of alternatives and request that they express preferences for one above the other. Even those individuals who find it impossible to define their goals are usually fairly

clear in stating their preferences when they are presented with alternate choices. By careful study of their selections, it is possible to gain a great deal of insight into the nature of the goals they are pursuing even though they themselves are not aware of them. This kind of OR approach applied to education will be valuable, Dr. Ackoff predicts, not so much for the problems it will solve but because of the questions that it will pose.

In further defense of his position that the application of operations research holds no grave danger for the human elements in the educational system, he points out that the OR practitioner has just as much right to conduct research on instruction and be in the classroom as the teacher. He reasons that there is just as much justification for the presence of one as for the other since no adequate criterion is available to determine precisely the degree of success or failure (benefit or harm to the students) of the performance of either.

With tongue in cheek, Dr. Ackoff agrees with critics who hold that education's problems are more complex than any other kind of problems, inferring that they are thus too complicated to be solved by operations research techniques. He observes that, in his knowledge, the only complete generalization ever obtained by OR is the statement that "everybodys' problems are more complicated than anybody else's problems and, by corollary, familiarity breeds complexity." Perhaps this is the reason that operations research has acquired its reputation as a tool for coping with complexity.

All five of the conference primary authors seem to agree that neither the systems approach nor the techniques of operations research hold any grave philosophical threat. Instead, they foresee many benefits accruing to the individual as well as to the total system as a result of this type of research being applied to the problems of education.

The final chapter which follows presents the participants' points of view regarding the accomplishments of the conference and lists some outcomes they expect may occur as a result of the discussions at Syracuse.

CHAPTER VII

Summary and Forecast

To arrive at a degree of closure and provide each delegate an opportunity to participate in the summary discussion, the conference was divided into work groups with one of the OR specialists serving as advisor in each group. This final chapter presents a compendium of the reports from the groups as they considered the major question posed by the conference: What can a systems approach, utilizing the techniques of operations research, accomplish for American education in general and instructional media research in particular?

Statements from the groups are summarized under five general classifications:

1. General values of OR
2. Specific contributions of OR to education
3. Specific contributions of OR to instructional media research
4. Possible results of the use of OR in education
5. Some difficulties which might arise from the application of OR to education

General Values of OR

Operations Research is characterized by its comprehensive approach to an investigation. OR can assist educators by providing them with a more inclusive overview of the complex problems of American education. All of the groups agreed that OR is an extremely valuable tool to be

used in formulating and actually forcing the specification of educational objectives -- both theoretical and behavioral. In addition, OR, through its intrinsic methodology, can provide American education with explicit, theoretical and behavioral problem-solving alternatives. Because OR forces a severe self-inspection and self-evaluation, it may have a slightly traumatic effect on those who must face the choices inherent in its decision-making aspects. It seemed obvious to all of the groups that OR may be applied at all levels of the educational spectrum.

Specific Contributions of OR to Education

Participants are hopeful that OR techniques may provide educational administrators with the tools they need for solving many of the complex problems they now face. It was suggested, facetiously, that OR might even indicate that greater monetary investment in administration could be much more effective in improving education than a similar expenditure of funds for new instructional media. The OR practitioner is regarded as a "thorn-in-the-side" who continually asks impertinent questions that require soul-searching answers, leading to a reexamination of objectives, methods, curriculum and administrative procedures. The techniques of operations research may prove helpful in specifying the type of educational product that should be generated by American education at the elementary, secondary, college and graduate school levels. Participants expressed concern about the difficulty of changing the behavior of already-trained teachers once OR has helped to specify new or revised theoretical and behavioral objectives for these teachers. They foresee a possibility that investigations utilizing OR in teacher-education programs could result in a complete re-evaluation of teacher preparation patterns and produce new

configurations of time, space and content.

Specific Contributions of OR to Instructional Media Research

Conference delegates acknowledge that OR possesses the tools for estimating quite accurately the costs of education and, therefore, can establish monetary values for research on instructional media. Resource allocations, the cost of backup personnel and facilities, in addition to other media research problems, can be designated specifically and placed in proper perspective. The general consequences to the educational system of educational TV and other media can be seen better through the use of OR. It can also assess and evaluate problems involving such trade-off values as (a) the percentage of effort that should be devoted to media research and media utilization in contrast to obtaining better teachers, (b) the percentage of time that should be spent on preparation of materials as contrasted with the percentage of time to be spent in presenting materials to students, and (c) the percentage of time that should be spent by pupils in learning situations while in school as contrasted with learning time spent outside the school environment. Before teachers can fully utilize the new media of instruction to best advantage, they must have more information based on the results of media research than is now available from traditional research studies.

(Addressing the conference in the role of university administrator, Dr. Kenneth Williams predicted that the techniques of operations research will prove extremely valuable in determining the optimum mix in assigning student time to lectures, laboratory work and independent study in order to achieve specified objectives at the upper division and graduate level

of higher education.)

Members of the discussion groups hold the opinion that OR can be extremely useful in facilitating the implementation of research results and agree that the U.S. Office of Education should continue to sponsor the integration of research knowledge related to new instructional media.

Possible Outcomes of OR in Education

The act of analysis -- the basic tenet of operations research -- leading to a model of an educational system is a valuable exercise in educational thinking, delegates believe, emphasizing that intelligent use of the scientific method is the basis for most successful research. OR, they hold, forces the use of the scientific method and permits control of multiple variables while keeping them in their proper context. In essence, OR is an attempt, within research methodology, to replace what has been an art with a technology. In a university situation, the techniques of operations research can be utilized to train researchers by means of a doctoral thesis matrix. In such a matrix, doctoral students would be members of OR teams. They would obtain their dissertation material and earn their degrees by participating in specific research assignments that would be parts of a larger research project.

Conference participants expect that, within the media field, operations research may help to answer such questions as:

> How do you establish an optimum flow of instructional materials in an educational system?
>
> How do you define instructional media? Operationally? Descriptively?

Does the word "media" describe the materials themselves or does it refer to the channels for the dissemination of ideas, facts and concepts?

Some Difficulties in the Use of OR in Education

In the opinion of some delegates, OR may be difficult to utilize in several areas of education. Assigning utilities and priorities to educational objectives may be hard to achieve in actual practice because there are real differences among attitudes held by the people who control education in the United States. Another perceived drawback is cultural resistance among the possible users of completed research, especially when the results involve criterion changes. Admittedly, Dr. VanderMeer's technological model of an instructional system which was referred to in Chapter IV might accomplish most of the specific educational objectives within the confines of the home. On the other hand, it would eliminate the baby-sitting function of traditional school organizations and create a change in criterion that would involve a great deal of cultural conflict.

A few participants expressed confusion about the size of the system to be researched. They were concerned about defining a system large enough to explicate fully the relevant variables in order to insure generalizability when, paradoxically, a smaller system permits tighter control over the variables and, perhaps, far greater precision of results. Some delegates expressed concern about the possibility that operations research would specify educational outcomes so precisely that a philosophical argument between determinism and free will would ensue. The question was raised: Will an environment in which students are free to grow as

they choose be superior to an environment where an attempt is made to specify the end product and, by manipulating existing conditions, to produce that product? The question, they feel, involves a priority of objectives and a willingness to accept the responsibility for the actual controls to be used. This regard for the philosophical implications of the use of OR in education can be summarized by the following statement from Dr. Burns paper:

> OR....may well help us determine what the actual outcomes of education empirically are; but taken alone it cannot reveal what the ends or fundamental purposes of education should be. Indeed, ...the prior definition of end is a necessary but insufficient condition of fruitful systems analysis.

Dr. Paul W. F. Witt accepted the task of summarizing the proceedings of the conference and presented his report to the delegates during the final session. It was divided into two sections:

Part I, News -- A survey of responses from the twenty-one participants who replied to his earlier request for individual reactions and reflections concerning conference proceedings.

Part II, Editorial -- His own personal observations and opinions.

A condensed version of Dr. Witt's summary report follows.

News

Delegates were asked to list the most significant ideas that had emerged from conference presentations and discussions, with special emphasis on new dimensions for research in educational media and possible uses of OR in media research.

Most of the twenty-one respondents indicated a favorable attitude

toward OR and predicted that the technique has great potential for improving education. One person stated that OR would be particularly useful in forcing educators to specify much more clearly than usual the outcomes desired as a result of instructional procedures. Another suggested that the technique of choosing among alternatives to reveal implicit values or goals is a very important characteristic of the OR approach. OR will permit analysis of sub-systems in instructional environments such as: (1) team teaching, (2) ungraded instruction, (3) programed materials and (4) independent studies, so as to optimize the effectiveness of each, separately and in combination. One individual felt that OR will make it possible for us to do: (1) basic research on learning and the mediation of learning and (2) to analyze the instructor's role as it relates to the design of instruction and/or media presentations. Another participant thought that OR has a potential for developing new research designs, as well as increasing the possibility of more effective applications of research results. Further, OR might prevent the misapplication of research tools, specifically statistics.

Simulation, an OR tool, is considered to be a device which can generate hypotheses without disturbing the operational system. A great deal of interest was evidenced in regard to both model building and simulation, with specific statements by participants that important new ideas had come to them at the conference regarding future research projects that will utilize simulated instructional systems. One individual suggested an analysis and study of the operation and effectiveness of an entirely new kind of public school.

Other comments by delegates include:

1. There is a need for developing instructional systems specifically designed for disadvantaged children and youth.
2. Teachers need to be taught to perform their role in these projected systems.

   (Dr. Peter Muirhead, conference representative from the U.S. Office of Education, considers the improvement of education for socio-economically deprived children to be one of the biggest problems facing America today. Its solution, he believes, requires new and specifically designed instructional materials plus teachers who are specially trained in techniques that are effective with underprivileged children.)
3. It is important that we study such factors as the effect of instructional television in living quarters and the problems of logistics in the distribution and production of instructional media and media services.
4. There is a need to study the effects of widespread use of television in higher education.
5. Some pointed observations about OR:
   a. It is a method of approaching a problem rather than a series of techniques,
   b. It is the application of the scientific method to problem solving,
   c. It is as good as the man or men who use it,

d. It is generalizable to the extent of the validity of the model,

e. Is OR a science or is it essentially an art?

f. Don't expect too much from OR until we, the educators, do our own homework--learning more about learning theory, the role of the teacher and how humans communicate effectively,

g. OR persons, admittedly, know little about the field of education and also should do some homework.

Editorial

Presenting his personal observations and reflections in the form of titles of editorials that may someday be written, Dr. Witt commented:

1. "Education doctors enter the OR kindergarten, wide eyed and open mouthed, but with great eagerness and high optimism!"
2. "Educators are confronted with the harsh reality that they don't really know where they are headed -- are told they must specify in behavioral terms the objectives of their instructional systems. They are also reminded of the inter-relationship of ends and means."
3. "Present and future demands on education make mandatory a more clearly directed and a more effectively and efficiently operated educational system. It is essential that we break out of the shackles of our present patterns of thinking and working!"

4. "Education is a dynamic force in our society, we have an obligation to do research that will make clear-cut the value of the investment!"
5. "Educators recognize OR as a tool of high potential in educational research. They say it can be helpful in revealing implicit values and objectives, in exploring existing myths in education, in testing ideas regarding ways in which education should be organized and operated, in determining the contributions of various media to learning, in determining the proper mix of all media used in an instructional system!"
6. "Educators wanted to be special but OR experts tell them education is not unique as an area in which OR might be used. OR is known to be a potential threat to existing administrative practice. Does your Dean know?"
7. "The term OR is used as a label for many different ideas and operations. OR experts strongly suspect that the term is merely a verbalism to many educators who are therefore in danger of being labeled faddists!"
8. "OR is characterized by reliance on the scientific method and the use of competencies of all pertinent specialists. Two heads, they say, if they are good heads are still better than one head, even a good head!"
9. "Those who should know, the OR experts, build an escape hatch, claim OR not a panacea for all educational evils.

Those who should know, the educators, emphasize the imperative need for a large scale, coordinated, adequately supported, basic research effort focused on learning as a natural phenomenon!"

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The Syracuse Conference "To Develop New Dimensions for Research in Educational Media Implied by The Systems Approach to Instruction" was convened because of concern among researchers and users of research that present research efforts involving the new educational media were of limited utility in actually modifying instructional practice. It was felt that efforts to conduct operational research studies aimed at modifying practices were often criticized and discredited because of inadequate definition of objectives and questionable methodology. It was also held that the systems approach to instruction, implying the optimum combination of man-machine resources, might provide the bases for new kinds of educational media research.

A review of the conference proceedings and papers reveals several striking and important insights. First, both educators and OR specialists discovered that for the most part, they were able to appreciate each other's position. Discourse could occur, ideas could be communicated, and understandings could result from an interchange of challenging concepts. Second, new research techniques, as far as educational research practices are concerned, were suggested and discussed; great enthusiasm was generated for a more global and scientific approach to the solution of educational

and instructional media problems. Third, hope was expressed for ultimate agreement on the ends of American education in order to provide a base for conducting operations research on traditional instructional systems so that new and improved systems may be developed. Finally, both educators and OR scientists seem to agree that further study on the part of each -- educator and scientist -- will facilitate the use of new research methodologies in solving the complex problems of American education, in general, and media research in particular.

GLOSSARY

Audiovisual describes instructional materials and techniques having sensory appeal that are used to make abstract (verbal) concepts more concrete (perceptual) for the learner.

Automation is the state resulting from the replacement of man with a machine as the source of control in the performance of either sensory or motor tasks.

Branching describes a self-instruction program that provides, at specified points, alternate routes toward the teaching objectives according to the ability of the learner. An incorrect answer to a question results in a student being led through a series of remedial steps; correct answers permit completion of the program in the shortest possible time. It is sometimes called intrinsic programing, its opposite is linear programing.

Computer is an electronic device that operates at rapid speed to carry out highly complex tasks involving logic and decision-making. Its raw material

Computer (continued)	is data which is designated input; the results of its operation are termed output. (or, according to IBM, -- a device which can accept information and supply information. The supplied output information is derived from the accepted input information.)
Constant	in operations research, describes a factor or element that does not change during the analysis. It is the opposite of a variable.
Criterion	is the expressed goal of an operations research analysis and must be specified with mathematical precision.
Data	are the raw materials -- both numerical and alphabetical facts -- that are supplied to a computer. It may also be described as input.
Decomposition	is a technique utilized in operations research to facilitate assessing the true value of a single part of a system by determining its benefit to the whole system as well as the cost of its attaining a given level of benefit. Such assessment is accomplished by taking the system apart (decomposing it) in order to study each of the parts.

Discipline in operations research, refers to a branch of knowledge that incorporates research.

Educational Media (and especially "new" educational media) is a term used to describe such instructional materials and technological devices as television, teaching machines, programmed learning material, electronic learning laboratories, motion pictures, filmstrips, slides and recorders. It is often used interchangeably with instructional media.

Electronic Learning Laboratory consists of a series of tape recorders, earphones and microphones connected to a console where switches permit the instructor to communicate with all students simultaneously, or groups of selected students, or one student individually.

Element in operations research, designates the factors of the problem being analyzed. Elements may be either constant or variable.

Factor in operations research, used synonymously with element.

Feedback describes the reverse flow of information which permits a central regulatory apparatus to exert

Feedback (continued)	control on the basis of actual performance rather than expected performance.
Function	mathematically, and in operations research, a magnitude so related to another magnitude that values of the latter correspond to values of the former.
Housekeeping	is a technique of operations research suggested by C. West Churchman which involves straightening out an existing system by leaving the goals invariant while working only on the parts that are out of order.
Input	refers to data fed into a computer, or energy or activity fed into a system or receiver.
Interdisciplinary Team	is an essential component of operations research and is comprised of a number of scientists representing as many fields of study as necessary in order that they may consider and evaluate as wide a range of approaches to a problem as possible.
Instructional Media	see "Educational Media"
Interface Unit	describes an element which is interposed between two or more units to serve as a modulating agent.
Intrinsic Programing	see "Branching"

Linear Programing	describes a system of self-instruction that presents an identical sequence of information and questions to each student as he proceeds through the program and usually requires a constructed response which is then reinforced by confirmation of correctness. The opposite is branching or intrinsic programing.
Lock-step Concept	refers to the traditional method of progressing blocks of students through school grades on the basis of age rather than individual ability and achievement. Its opposite is the ungraded school where youngsters progress at their own rate of speed.
Media	the plural of medium, describes channels for distributing messages and includes television, radio, motion pictures, books, magazines and newspapers.
Model	is the representation of a system that is constructed by the operations research practitioner so that he can experiment with it. The model often takes the form of a mathematical equation.

Operations Research — is described by Russell Ackoff as research on problems involving the control of organized systems, through the application of scientific method by interdisciplinary teams. It is abbreviated OR. Some other terms used interchangeably include operations analysis, systems analysis, systems research and management science.

Optimize — in operations research, is to determine the best possible solution that will satisfy the particular goal or criterion of the problem.

Output — refers to information produced by a computer as well as to the product or signal resulting from the performance of a system or sender.

Parameter — is an arbitrary constant, as distinguished from a fixed or absolute constant.

Programed Instruction — is the utilization of programed material for self-teaching purposes. The program may be contained in a machine, or in a workbook or textbook, and usually consists of a series of items, statements or questions to which the student must respond. Instructional programs are classified as either linear or branching.

Programing is the process of partitioning knowledge and skills into a carefully constructed sequence that leads to precisely prescribed instructional goals. The result is termed a program. Programing also describes a method of feeding information into a computer for analysis.

Queuing in operations research, describes the condition that exists when a job is not done at the time it needs to be done, resulting in a line of entities -- customers, cars or raw materials -- waiting to be served.

Scientific Method is described as a self-correcting process of inquiry based upon fact and aimed at verifiable prediction.

Simulator is a mechanism that is constructed specifically to imitate a particular process or operation.

Simulation in operations research, describes the process of experimenting symbolically on a model in order to derive the best possible solution to a problem. The process may be repeated, with changes introduced, as many times as necessary.

Sub-system in operations research, is a dependently operating part of a larger system or organization.

System — in operations research, is defined as an organized whole -- comprised of man and/or machines -- in which the behavior of any one part ultimately has some effect on one or more of the other parts. The interacting parts all have a common purpose even though they are not necessarily controlled from a central point.

Systems Analysis — See "Operations Research"

Systems Research — See "Operations Research"

Systems Approach — implies the application of the optimum combination of man and machine resources to the solution of problems. It indicates a comprehensive approach that considers all relevant factors and concepts.

Teaching Machine — is a mechanical device that presents information to a student in a carefully determined sequence called a program. Responses are usually required from the student as he proceeds through the program.

Team Teaching — describes the utilization of a number of instructors, each of whom has been trained in general educational methods and materials as well as in a particular speciality. Usually, a master teacher heads the team which is jointly responsible for instructing

Team Teaching (continued) a large number of students. The approach is used particularly at the elementary level and consists of large group lectures, small group discussions and very small tutorials for remedial work.

Technology is a science which stresses a utilitarian application of basic scientific research.

Ungraded school describes an educational institution, usually at the elementary level, where youngsters progress at their own rate of speed through the curriculum regardless of age. A seven-year-old could be assigned to a reading group with mostly ten-year-olds, an arithmetic group with other seven-year-olds or with younger pupils, according to individual ability in each particular area. The opposite is referred to as the lock-step concept.

Variable in operations research, describes a factor or element of a problem that changes from time to time or situation to situation. It is the opposite of a constant.